# INDOOR AIR QUALITY ASSESSMENT

**Priest Street School**
**115 Priest Street**
**Leominster, Massachusetts**


Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program

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## Background/Introduction

At the request of Christopher Knuth, Director, Leominster Board of Health, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health's (CEH) Bureau of Environmental Health Assessment (BEHA) conducted an assessment of the indoor air quality at the Priest Street School (the school), 115 Priest Street, Leominster, Massachusetts. Concerns about mold growth and other indoor air quality conditions in the modular classroom structure prompted the request.

On June 11, 2004, Michael Feeney, Director, Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, visited the school to conduct an indoor air quality assessment. Mr. Feeney was accompanied by David Wood, Director of Facilities, Leominster Public Schools and for portions of the assessment, Mr. Knuth.

The main school building is a brick and wood structure built in 1894. Wings were added to the building in 1918. The modular building is a freestanding structure that was erected at the rear of the main building in 1994. The main building contains nine classrooms, cafeteria and offices. The main building is the subject of this report. Windows are openable throughout the school. The assessment of the modular classroom building is the subject of a separate report.

## Methods

BEHA staff performed visual inspection of building materials for water damage and/or microbial growth. Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particulate matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

## Results

The school houses approximately 290 students in kindergarten through first grade and has a staff of approximately 35. Tests were taken during normal operations at the school and appear in Table 1.

## Discussion

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million of air (ppm) in all but one area surveyed (classroom 3), which indicates adequate ventilation in most areas of the building. It is important to note that some classrooms had open windows or were sparsely occupied during the assessment however, which can greatly reduce carbon dioxide levels.

This building does not have a modern mechanical ventilation system (except in the basement classroom), but uses a natural/gravity ventilation system to provide airflow to classrooms in combination with openable windows. Ventilation is provided by a series of louvered vents. Each classroom has an approximately 3′ x 3′ grated air vent in the center of an interior wall near the ceiling, which is connected by an airshaft to the school boiler (Picture 1). A corresponding 3′ x 3′ vent exists in each room near the classroom doorways that is connected to an exhaust ventilation shaft that runs through the roof to the basement (Picture 2). These exhaust ventilation shafts are connected by basement passageways to the back of the building. The building has two of these shafts on either side. Classrooms were constructed around these shafts to provide exhaust ventilation. Each of these ventilation shafts terminates in a "hearth"-like opening in the basement.

Air movement is provided by the stack effect. The heating elements warm the air, which rises up the hot air ventilation shafts. As the heated air rises, negative pressure is created, which draws cold air from the basement area into the heating elements. This system is designed to draw air from two sources in the basement: fresh air from a hinged window-pulley system on the exterior wall of the building and return air from the exhaust ventilation shafts. These sources of air mix in the basement prior to being drawn into the heating elements. The percentage of fresh air to return air is controlled by the hinged window-pulley system. The chains of the pulley system are designed to lock the hinged window at a desired angle to limit fresh air intake. Fresh air in winter is supplied throughout the building by the hot air vents.

Exhaust ventilation is provided by floor level vents. As the heating elements draw air into the hot air ducts, return air is drawn from the "hearths" at the bottom of the exhaust ventilation shafts. Negative pressure is created in these shafts, which in turn draws air into the cool air vents of each classroom. The draw of air into these cool air vents is also controlled by a draw chain pulley system. A percentage of return air rises up the ventilation shaft to exhaust outdoors. These vents were blocked with furniture and other materials at the time of the assessment.

The basement classroom was retrofitted with a unit ventilator (univent) (Picture 3). Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building and return air through an air intake located at the base of each unit. Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit (Figure 1). Exhaust ventilation capacity exists in this room, however, at the time of the assessment the univent was deactivated.

In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last balancing of the systems installed in the basement was not available at the time of the assessment.

During summer months, ventilation is controlled by the use of openable windows in classrooms. This section of the school was configured in a manner to use cross-ventilation to provide comfort for building occupants. The building is equipped with windows on opposing exterior walls. This design allows for airflow to enter an open window, pass through a classroom, pass through the open hallway door, enter the hallway, and exit the building on the leeward side (opposite the windward side) (Figure 2). With all windows and hallway doors open, airflow can be maintained in a building regardless of the direction of the wind. This system fails if the windows or hallway doors are closed (Figure 3). Most hallway doors were closed during the assessment, which can inhibit airflow. Since the exhaust ventilation system is non-mechanical, no airflow is created by this system once the boiler system is deactivated. Therefore, to increase airflow, cross ventilation using windows should be used to create airflow in this section of the building.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied.

Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature readings were measured in a range of 72$^{o}$ F to 75$^{o}$ F, which were within BEHA comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range between 70$^{o}$ F to 78$^{o}$ F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. It is often difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (exhaust vents blocked/pull-chains and pulleys broken).

The relative humidity measurements in the building ranged from 25 to 33 percent, which were below the BEHA recommended comfort range. The BEHA recommends that indoor air relative humidity is comfortable in a range of 40 to 60 percent. It is important to note that relative humidity measured indoors exceeded outdoor measurements during air testing conducted when the building was occupied (range +1 to +6 percent). The increase in relative humidity during occupancy indicates that the likely source of water vapor in the building is the occupants. Moisture removal is important since the sensation of heat conditions increases as relative humidity increases (the relationship between temperature and relative humidity is called the heat index). As indoor temperature rises, the addition of more relative humidity will make occupants feel hotter. If moisture is removed, the comfort of the individuals is increased. Removal of moisture from the air, however, can have some negative effects. Relative humidity in the building would be expected to drop below comfort levels during the heating season. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northeast part of the United States.

**Other Concerns**

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants; however, the pollutant produced is dependent on the material combusted. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. According to the NAAQS established by the USEPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a). Outdoor carbon monoxide concentrations were non-detectable or ND (Table 2). Carbon monoxide levels measured in the school were also ND. *Carbon monoxide should not be present in a typical, indoor environment*. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels.

Several air quality standards have been established to address airborne pollutants and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997).

As previously mentioned, the US EPA also established NAAQS for exposure to particulate matter. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particle levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment. Outdoor PM2.5 concentrations were measured at 3 $\mu g/m^3$. Indoor levels of PM2.5 ranged from 2 to 9 $\mu g/m^3$, which in most cases reflected outdoor levels and did not exceed the NAAQS (Table 1).

Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in window-mounted air conditioners, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND. Indoor TVOC concentrations were also ND. Please note, that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products.

Several other conditions were noted during the assessment, which can affect indoor air quality. Of note was the amount of materials stored inside classrooms. In classrooms throughout the school, items were observed on windowsills, tabletops, counters, bookcases and desks. The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) also make it difficult for custodial staff to clean. Dust can be irritating to eyes, nose and respiratory tract. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

Cleaning products and other chemicals were found in several classrooms. Cleaning products contain chemicals (such as bleach or ammonia-related compounds), which can be irritating to the eyes, nose and throat. These items should be stored properly and out of the reach of students.

Latex gloves are used by the custodial staff. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998).

## Conclusions/Recommendations

In order to address the conditions listed in this assessment, the following recommendations are made to improve indoor air quality.

1. Remove materials blocking exhaust vents in classrooms.
2. Repair the pulley chain/louver systems in vents as needed to provide ventilation as designed.
3. Operate the basement classroom univent during school hours continuously. Examine each univent for function. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers.
4. Use open hallway doors and windows to enhance airflow. Be sure to close hallway doors and windows at the end of the school day. To aid in the draw of fresh outdoor air in warm weather, use portable fans directing air out windows on the leeward side (opposite the windward side) of the building. Fans positioned in this manner will serve to increase the draw of outdoor air across a school floor without interfering with the natural internal airflow pattern of the building.
5. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative

humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (e.g., throat and sinus irritations).

6. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
7. Store cleaning products properly and out of reach of students. Refrain from using strong scented and/or VOC-containing materials.
8. Obtain non-latex containing gloves for custodial use.

## References


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**Figure 2** **Cross Ventilation in a Building Using Open Windows and Transoms**

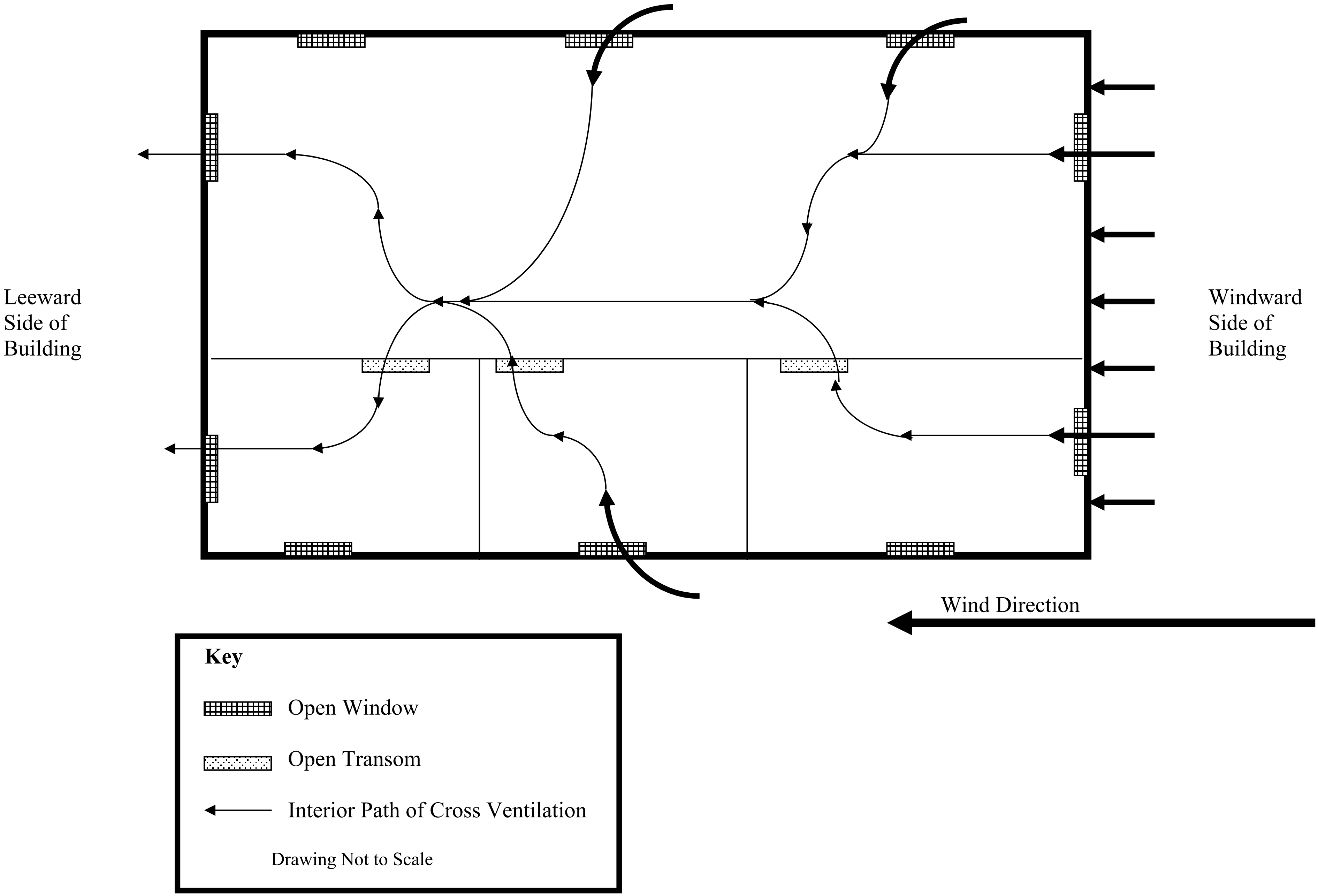
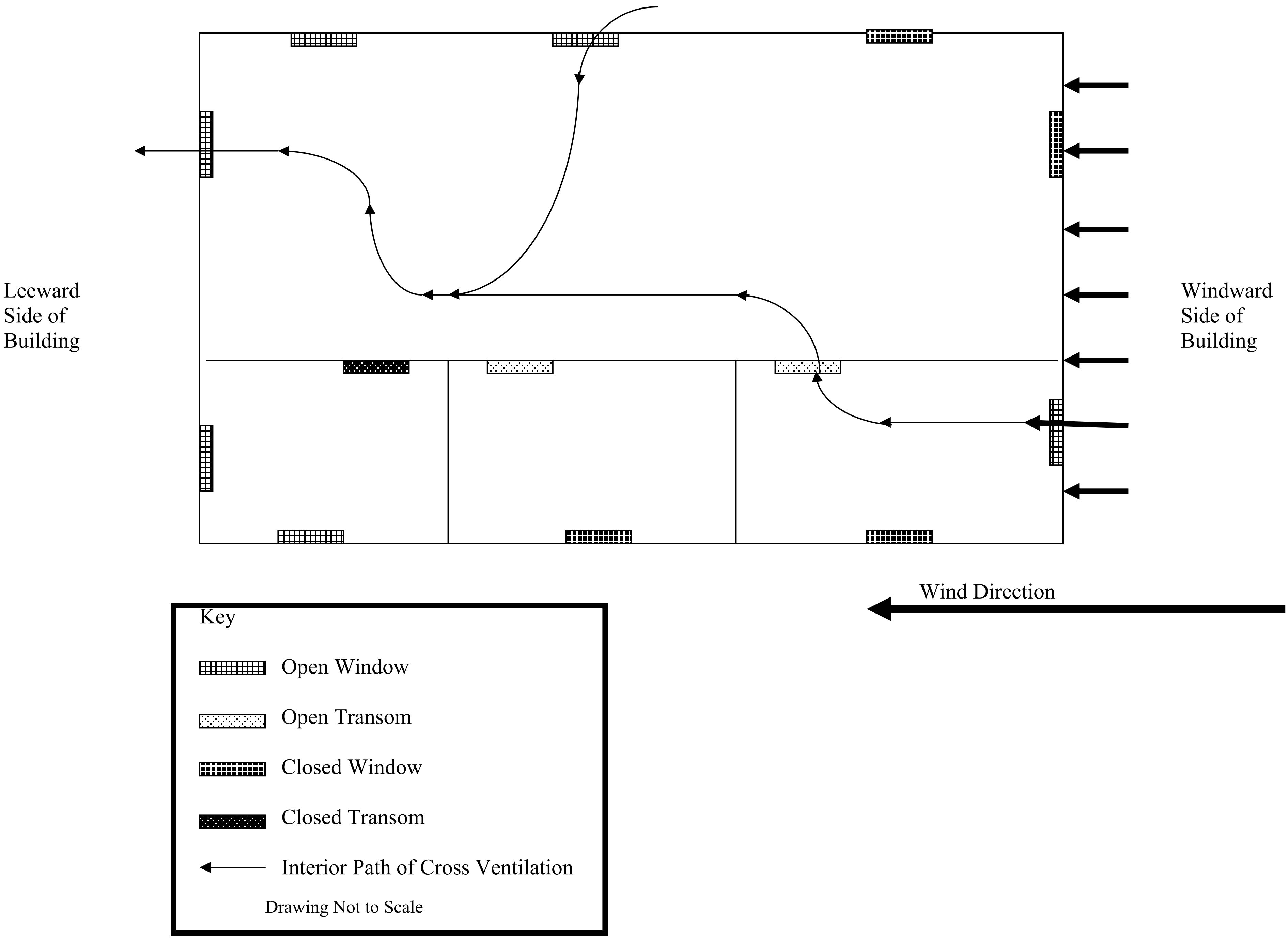


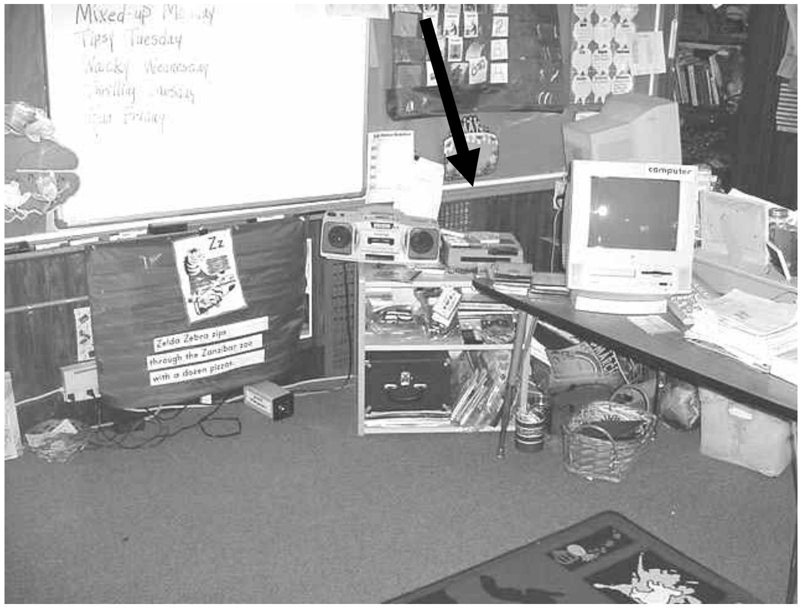
**Figure 3** **Inhibition of Cross Ventilation in a Building with Several Windows and Transoms Closed**



**Picture 1**


**Fresh Air Supply, Natural Gravity System**

**Picture 2**




**Exhaust Vent, Natural Gravity System**

**Picture 3**


**Basement Classroom Univent**

**Priest Street School, Main Building** **Indoor Air Results**

**115 Priest Street, Leominster, MA** **June 11, 2004**

# Table 1

| Location/ Room | Temp (°F) | Relative Humidity (%) | Carbon Dioxide (*ppm) | Carbon Monoxide (*ppm) | TVOCs (*ppm) | PM2.5 (µg/m3) | Occupants in Room | Windows Openable | Ventilation Supply | Ventilation Exhaust | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Background (Outdoors) | 73 | 23 | 397 | ND | ND | 3 | - | - | - | - | |
| Cafeteria | 72 | 27 | 526 | ND | ND | 3 | 30+ | Y | N | N | 12 computers |
| 5 | 72 | 28 | 507 | ND | ND | 3 | 1 | Y | Y | Y | |
| 6 | 73 | 29 | 584 | ND | ND | 3 | 0 | Y | Y | Y | Exhaust vent blocked with furniture |
| 7 | 74 | 33 | 699 | ND | ND | 3 | 1 | Y | Y | Y | Exhaust vent blocked with box |
| 8 | 75 | 25 | 583 | ND | ND | 3 | 0 | Y | Y | Y | Exhaust vent blocked with furniture |
| 1 | 75 | 25 | 584 | ND | ND | 3 | 19 | Y | Y | Y | Exhaust vent blocked with cabinet |
| 2 | 74 | 30 | 570 | ND | ND | 3 | 0 | Y | Y | Y | Exhaust vent blocked with furniture |

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
WP = wall plaster

**Comfort Guidelines**

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

**Priest Street School, Main Building**

**115 Priest Street, Leominster, MA**

**Indoor Air Results**

**June 11, 2004**

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|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 74 | 33 | 1500 | ND | ND | 9 | 18 | Y | Y | Y | Exhaust vent blocked with table |
| 4 | 74 | 25 | 526 | ND | ND | 2 | 18 | Y | Y | Y | Exhaust vent blocked with table |
| Basement classroom | 73 | 32 | 574 | ND | ND | 3 | 0 | Y | Y | N | Aquarium<br>Univent return vent occluded with dust |

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